Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 11(6): 1782, 1 November 2015 doi: http://dx.doi.org/10.15560/11.6.1782
ISSN 1809-127X

Small non-volant mammals (Didelphimorphia and Rodentia) from the RPPN Guarirú, an Atlantic Forest fragment in northeastern Brazil

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Abstract: Due to the very rare mammal inventories in the northern half of the Atlantic Forest in the state of Bahia, Brazil, all initiatives to increase the knowledge of the group in this region are greatly appreciated. Thus, herein we present an inventory conducted in the privately owned Guarirú Nature Reserve, a fragment of Atlantic Forest in several conservation/regeneration stages. Sampling was carried out using Tomahawk, Sherman, and Pitfall traps over one year. The sampling resulted in 154 captures of 93 individuals from 12 different species. The didelphids *Didelphis aurita*, *Gracilinanus microtarsus*, *Marmosa murina*, *Marmosops incanus*, *Metachirus nudicaudatus*, *Micoureus paraguayanus*, and *Monodelphis americana* were recorded, as well as the cricetids *Akodon cursor*, *Oligoryzomys* sp., and *Rhipidomys* sp., and the echimyids *Trinomys albispinus* and *T. setosus*. Given the relative lack of knowledge about this important portion of the Atlantic Forest this inventory is an important contribution to the mammalogy of Brazil.

Key words: rodents, Sigmodontinae, Echimyidae, marsupials, Didelphidae, Serra da Jiboia

INTRODUCTION

Very little research dealing with mammal faunas have been conducted in the extreme north of the Atlantic Forest Central Corridor, particularly in the mountain chain known as Serra da Jiboia, in the state of Bahia, Brazil, surrounded by the Caatinga biome. In this region, knowledge about mammal richness is restricted to three scientific contributions: an abstract presented in a regional meeting at the end of the 1990s (Morais and Freitas 1999), where the presence of 41 mammal species in the Serra da Jiboia were cited, although only eight were effectively listed; a paper by Encarnação et al. (2000) dealing with one of the species [*Callistomys pictus* (Pictet, 1841)] listed in Morais and Freitas (1999); and another abstract presented in a national meeting by Borges and Scherer (2012), dealing with medium-sized mammals from the same area studied in the present contribution.

Due to the fact that the Atlantic Forest is one of the Brazilian biomes with the greatest mammal richness (Paglia et al. 2012), the current paper tries to mitigate the lack of knowledge in this part of Brazil, presenting an inventory of the non-volant mammal fauna in a privately owned Nature Reserve (RPPN, in the Portuguese acronym).

MATERIALS AND METHODS

Study site

The area where the research was performed is a 41 ha forest fragment named RPPN Guarirú (12°51′25.73″ S, 039°27′56.45″ W), located in the rural area of the Varzedo municipality, in the state of Bahia, Brazil, 200 km from the city of Salvador (Figure 1). The area is a mix of primary and secondary forest, this latter in different regeneration stages; there are also some grassy areas around the forest, some rocky outcrops inside it, and at least two small rivers crossing the area (Figure 1). The average rainfall over the year when the area was sampled was 67.63 mm per month (with minimum and maximum of 0 mm and 228 mm, respectively); the climate is tropical semi-humid and the annual average temperature is 22°C, varying with altitude (Tomasoni and Santos 2003); the altitudinal variation in the sampled area ranges from 520 m to 680 m high.

Data collection

Ten field expeditions were carried out from June 2012 to August 2013. The efforts were different from some of them since the number of trapping nights were four or five. The first three expeditions consisted of a pre-sampling period, whit a total of 39 live-traps in each one.

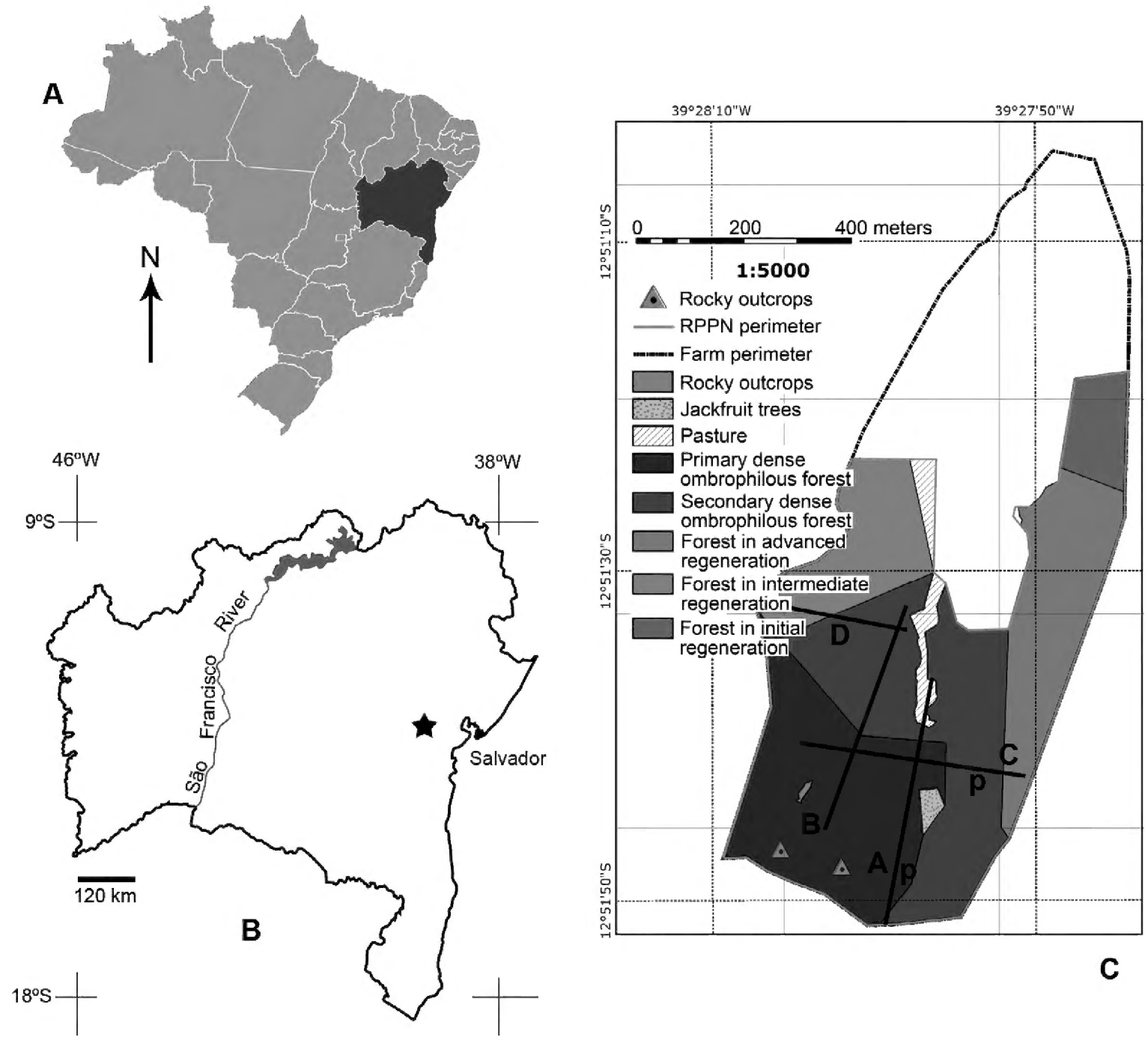

Figure 1. Location and vegetation composition of study site. A, map of Brazil with the state of Bahia highlighted. B, detail of the state of Bahia showing the location of RPPN Guarirú (star). C, vegetation constitution of the RPPN Guarirú, modified from Alexandrino et al. (2012). In C, the letters A to D represent the four transects established in the area (in the pre-sampling period the traps were placed in transect A); the letter "p" represents the pitfall trap sets.

Both Tomahawk (53 × 21 × 21 cm) and Sherman (30 × 9 × 9 cm) live-traps were distributed in a linear transect in an almost north-south direction inside the forested area (Figure 1, Transect A); the live-traps were spaced circa 30 meters from one another, with part of them placed over the ground and some on the vegetation (0.5 to 1.5 m high). In the remaining expeditions, the sampling design was modified, the traps being distributed in four transects, approximately 500 m long each (Figure 1). Each transect had 10 capture stations (one Tomahawk, on the ground, and one Sherman, on the vegetation). The live-traps of two transects were activated in alternate expeditions (Figure 1, Transects A and B in an expedition and C and D in the subsequent expedition), giving a 40 traps × night sampling effort. At the end of the sampling period, the total effort was 1,480 traps × night distributed over a total of 37 sampling nights. The Tomahawk traps were baited with pieces of banana and bacon, while the Sherman traps received a mix of peanut candy, banana, oiled sardines, cod liver oil, and corn meal (Grelle 2003). In addition to these live-traps, two pitfall trap sets were installed, each one with four 60 L buckets in a "Y" configuration (one central bucket and three terminal ones). The buckets were placed 10 m from one another linked by a plastic fence 50 cm high. Just one of the pitfall sets was activated in each field expedition giving a sampling effort of 156 buckets × night. This method is considered more efficient for capturing terrestrial or semi-fossorial mammals (Umetsu et al. 2006).

When captured, the animals were measured, weighed, sexed, identified, and tagged with metallic earrings (7 mm) to be released in the same capture site; if possible, the reproductive condition of the individuals was also verified. The non-collection of the individuals was a requirement of the RPPN owner when giving the authorization to carry out the research on his property, so some captured taxa were identified only to the genus level. The systematics used in this study follows the proposals of Wilson and Reeder (2005), Gardner (2007), Reis et al. (2011), and Bonvicino et al. (2008). Dr. Gilson Iack-Ximenes confirmed the identification of the echimyids. Individuals found dead inside the traps or that died during manipulation were collected; the taxidermyzed skins and the cleaned skeletons (by dermestids) were deposited in the Collection of Mammals of the Museum of Zoology of the Universidade Estadual de Feira de Santana (under

code MZFS DM). The research and the eventual collection of specimens were authorized by the Instituto Chico Mendes de Conservação da Biodiversidade (Authorization number 34864-2).

Data analysis

The software EstimateS 9.1.0 (Colwell and Coddington 1994; Colwell 2013) was used to build a species rarefaction curve and evaluate if the sampling effort was enough (with 1,000 randomizations); the same software enabled the comparison between observed and estimated richness.

RESULTS

At the end of the sampling period, 154 captures of 93 individuals from 12 species occurred (Figure 2; Tables 1 and 2). Only 10 captures occurred in pitfall traps (a success of 6.41%), and the remaining 144 captures were made by the Tomahawk and Sherman live-traps (success of 9.73%). The capture success was not calculated separately for the two kinds of live-traps due to the alteration of the sampling efforts during the first months of the research.

Two orders were represented, as usual in this kind of study, Didelphimorphia and Rodentia. The didelphimorphs represented 68.8% (*n*=64) of captured individuals and 66.2% (*n*=102) of captures, that include re-captures. Rodents, so far, represented 31.2% (*n*=29) of captured individuals and a total of 33.8% (*n*=52) of overall captures.

Seven didelphid species were recorded: *Didelphis aurita* (Wied-Neuwied, 1826), *Gracilinanus microtarsus* (Wagner, 1842), *Marmosa murina* (Linnaeus, 1758),

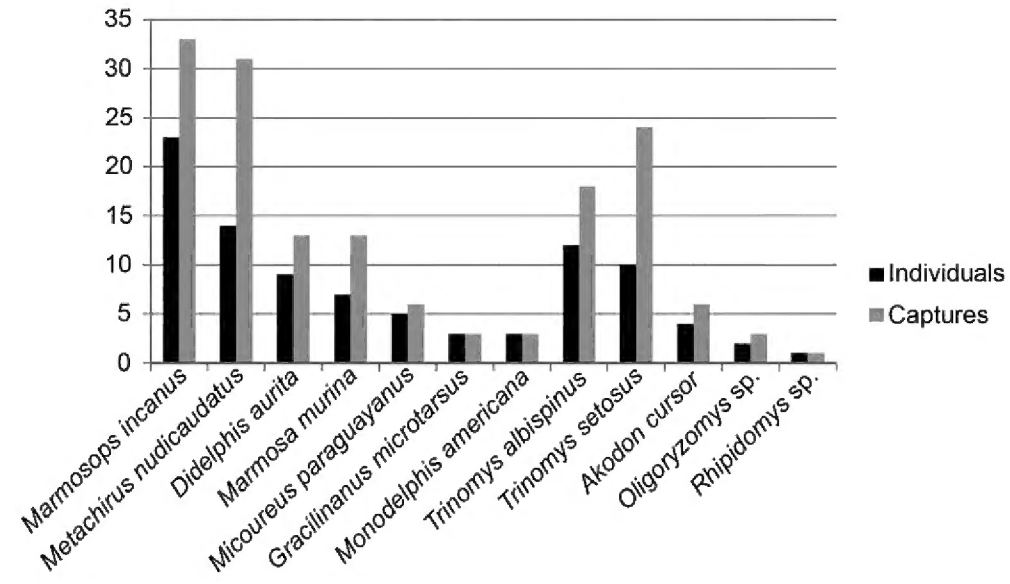

Figure 2. Abundance of the recorded taxa in the RPPN Guarirú.

Table 1. Data of captures per taxon.

Taxon	*n* (number of individuals)	Males	Females	*n* (total number of captures)	Collected specimens
Didelphis aurita	9	3	6	13	—
Gracilinanus microtarsus	3	0	3	3	1 (MZFS DM0369)
Marmosa murina	7	3	4	13	1 (MZFS DM0368)
Marmosops incanus	23	15	8	33	4 (MZFS DM0163, MZFS DM0200, MZFS DM0366, MZFS DM0595)
Metachirus nudicaudatus	14	5	9	31	—
Micoureus paraguayanus	5	3	2	6	—
Monodelphis americana	3	3	0	3	—
Akodon cursor	4	3	1	6	—
Oligoryzomys sp.	2	2	0	3	—
Rhipidomys sp.	1	1	0	1	—
Trinomys albispinus	12	7	5	18	1 (MZFS DM0162)
Trinomys setosus	10	4	6	24	2 (MZFS DM0365, MZFS DM0367)
Total	**93**	**49**	**44**	**154**	**9**

Table 2. Descriptive statistics based on measurements taken on captured individuals (lengths in millimeters and body mass in grams). BM, body mass; E, internal ear length; F, foot length, without claw; FC, foot length, with claw; HBL, head-body length; TL, tail length. Averages are shown with minimum and maximum values in parentheses, followed by number of individuals considered.

Taxon	HBL	TL	E	F	FC	BM
Didelphis aurita	302.2 (160–400) 9	307.3 (165–390) 9	37.7 (25–50) 8	46.6 (29–57) 7	50.7 (31–62) 7	810 (135–1,540) 9
Gracilinanus microtarsus	83.3 (76–90) 3	141 (130–160) 3	16 (15–17) 3	14 (13–15) 2	14.7 (13.5–16) 2	25 (20–35) 3
Marmosa murina	109 (94–126) 7	164.8 (152–174) 7	17.6 (14–19) 6	17.9 (16.5–19) 6	17.3 (15–19) 6	38.6 (25–50) 7
Marmosops incanus	117.5 (78–154) 22	155.1 (86–204) 22	20.9 (14–28) 19	17.6 (15–20.5) 17	19.1 (16–23) 17	48.7 (10–100) 22
Metachirus nudicaudatus	218.85 (133–280) 14	294.7 (183–340) 14	29.65 (24–35) 12	37.85 (28–43) 12	40.37 (35–45) 12	284.6 (65–390) 14
Micoureus paraguayanus	139 (125–165) 5	222.6 (201–248) 5	23.2 (20–25) 4	20.5 (19–21) 4	22.7 (21–24) 4	117 (80–170) 5
Monodelphis americana	85 (64–100) 3	44 (40–48) 3	9 1	14 1	14.5 1	23.5 (9.5–36) 3
Akodon cursor	101 (91–107) 4	96.75 (89-104) 4	14.5 (14–15) 4	23 (22.5–23.5) 4	24.87 (24.5–25) 4	46 (35–50) 4
Oligoryzomys sp.	109 (98–120) 2	132.5 (125–140) 2	16.5 (15.5–17.5) 2	27.5 (26.5–28.5) 2	28.75 (28–29.5) 2	35 (30–40) 2
Rhipidomys sp.	108 1	131 1	17 1	24 1	25.5 1	25 1
Trinomys albispinus	178.1 (163–205) 12	146.6 (132–168) 12	22.5 (17.5–25) 12	34.8 (31–38) 12	37.5 (35–41) 12	184.2 (130–220) 12
Trinomys setosus	186.7 (134–220) 10	184.9 (150–216) 9	24.2 (22–27.5) 10	43.2 (35–48.5) 10	46.6 (39–52.5) 10	219 (140–280) 10

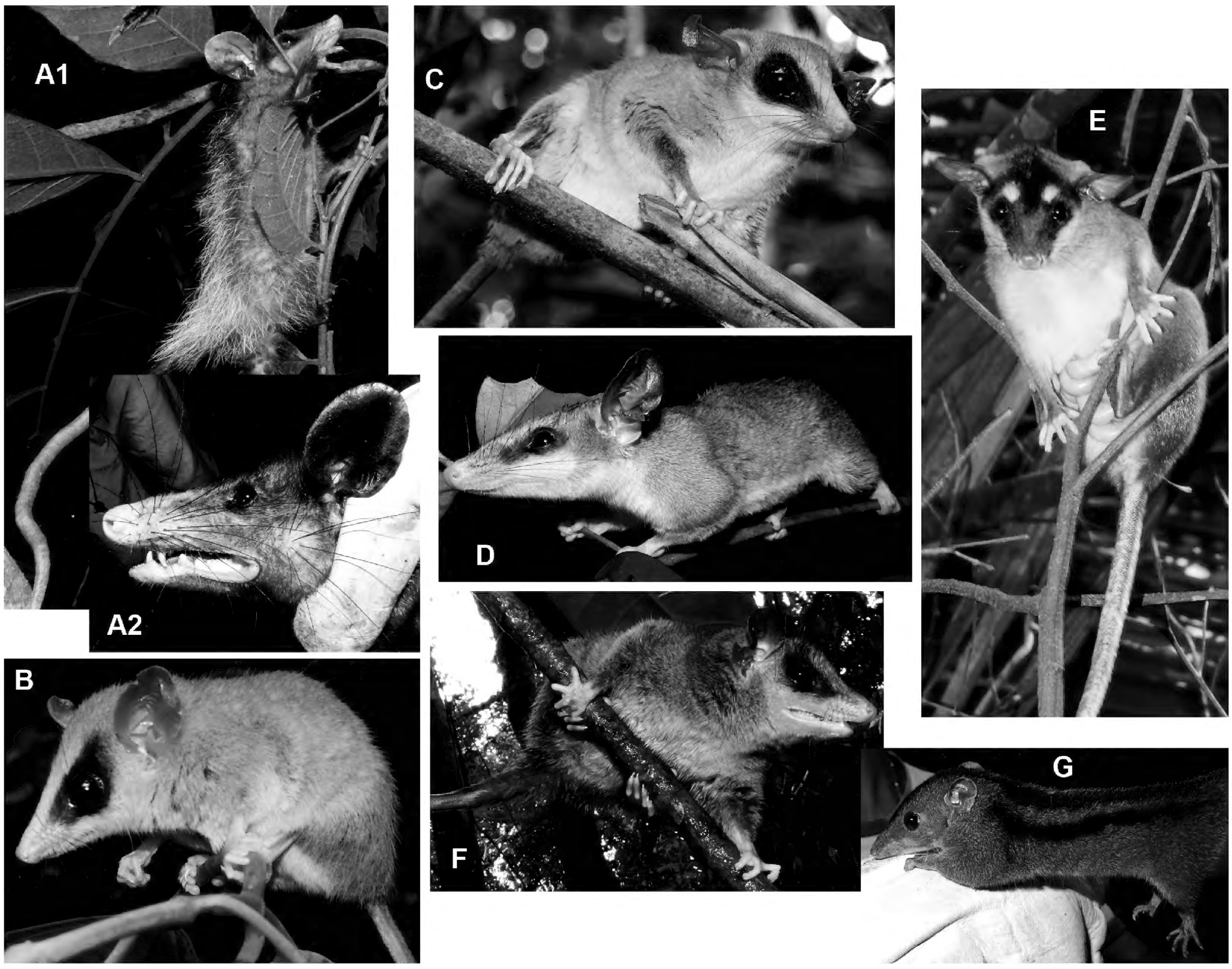

Figure 3. Didelphimorphs from the RPPN Guarirú. **A**, *Didelphis aurita* (A1, juvenile; A2, adult). **B**, *Gracilinanus microtarsus* (note that the very yellowish ear base is very different from the brown ear of *Marmosa murina*). **C**, *Marmosa murina*. **D**, *Marmosops incanus*. **E**, *Metachirus nudicaudatus* (with its offspring). **F**, *Micoureus paraguayanus*. **G**, *Monodelphis americana*. All photographs by the authors.

Marmosops incanus (Lund, 1840), *Metachirus nudicaudatus* (Desmarest, 1817), *Micoureus paraguayanus* (Tate, 1931), and *Monodelphis americana* (Müller, 1776) (Figure 3).

Several didelphids captured in the research offer information about the reproductive biology of the species in the study area. *Metachirus nudicaudatus* females with the mammary region reddish, furry and swollen were captured in August and November 2012, and March, May and June 2013; females with cubs were captured in September (without offspring in August) and November 2012, and February, May, and June 2013 (the same female captured with cubs in February 2013 and with swollen abdomen in May 2013). Some *M. nudicaudatus* males showed a pendent scrotum suggesting sexual activity, in August 2012 and August 2013. A female of *Didelphis aurita* was captured with well-developed cubs inside its marsupium in February 2013 and other two females showed the inner area of marsupium reddish and swollen in August 2012 and May 2013. Males of this species were captured in February and March 2013 with pendent scrotum.

Males of *Marmosops incanus* were captured in August, September and November 2012, and February, July and August 2013, suggesting sexual activity (pendent scrotum and reddish secretion on the throat region). No females of this species were captured with cubs, but at least two showed a swollen abdomen in February and August 2013; four very young males were captured in the pitfall traps in November 2012 without the mother presence.

Reproductive males of *Monodelphis americana*, *Micoureus paraguayanus* and *Marmosa murina* were captured in November 2012; females of the latter two species were captured in November 2012 and July 2013, respectively, showing reddish and swollen mammary area.

Among the five rodent species, two families were recorded: Cricetidae and Echimyidae. The cricetids were represented by *Akodon cursor* (Winge, 1887), *Oligoryzomys* sp., and *Rhipidomys* sp. (Figure 4), while *Trinomys setosus* (Desmarest, 1817) and *T. albispinus* (I. Geoffroy, 1838) were the recorded echimyids (Figure 5). *Trinomys*

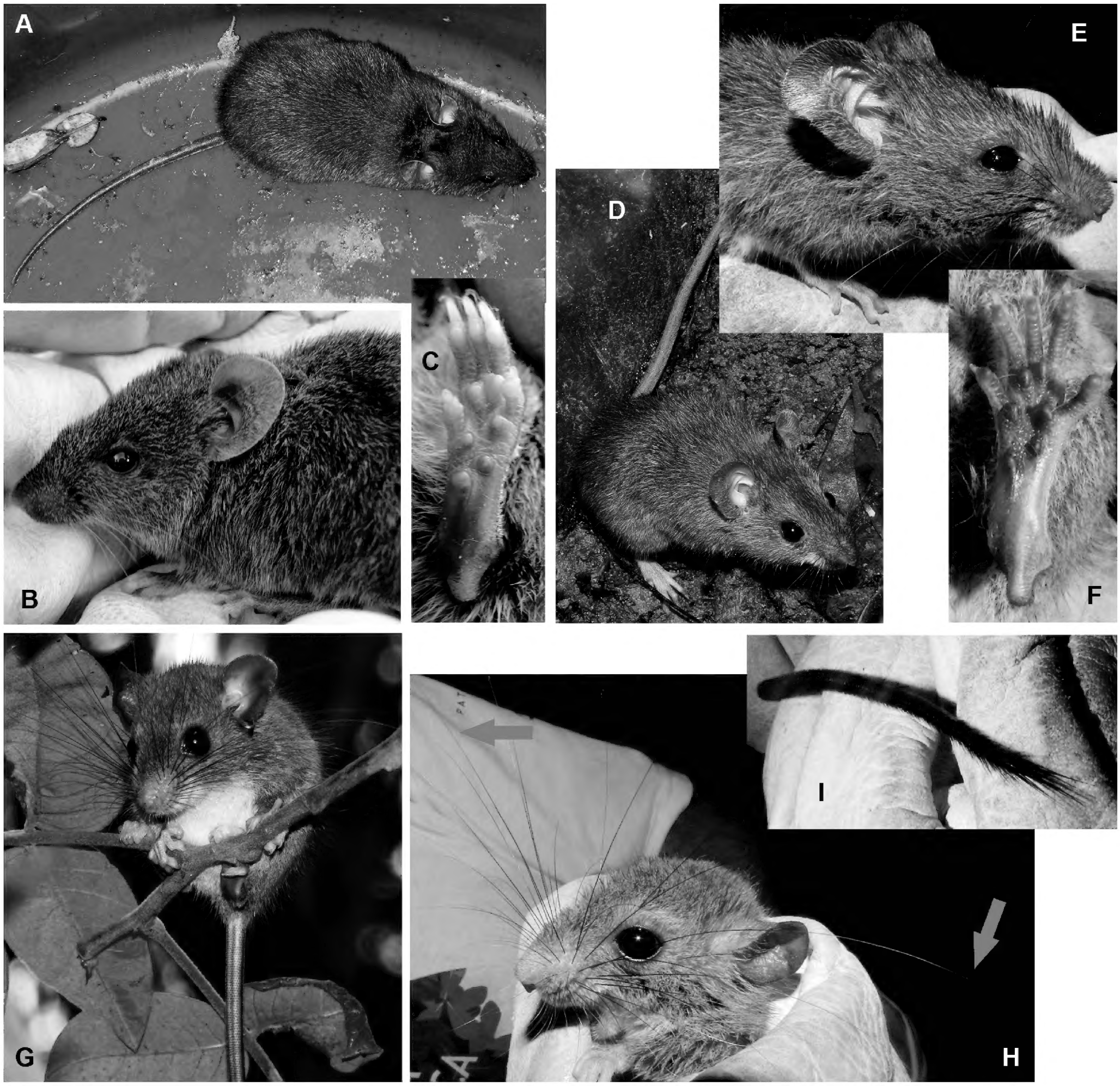

Figure 4. Cricetid rodents from the RPPN Guarirú. **A–C**, *Akodon cursor* (A, full body; B, detail of the head; C, detail of the left foot). **D–F**, *Oligoryzomys* sp. (D, full body; E, detail of the head; F, detail of the left foot). **G–I**, *Rhipidomys* sp. (G, full body; H, detail of the head, with arrows showing the very long vibrissae; I, detail of the tail showing a terminal brush). All photographs by the authors.

albispinus and *T. setosus* were collected and their identities were confirmed from the analysis of skull and dentition, according to Iack-Ximenes (2005) (Figure 6). Females of *Trinomys setosus* were captured in February 2013 and May 2013 with vaginal bleeding and perforated vagina, respectively; in May 2015 a female *T. albispinus* also showed vaginal bleeding.

Marmosops incanus ($n = 23$) and *Metachirus nudicaudatus* ($n = 14$) were the most abundant didelphids, while the echimyids *Trinomys albispinus* ($n = 12$) and *T. setosus* ($n = 10$) were the most abundant rodents (Figure 3). Among the didelphids, the rarest species were *Gracilinanus microtarsus* and *Monodelphis americana*, with only three captured individuals each. The cricetids *Rhipidomys* ($n = 1$) and *Oligoryzomys* ($n = 2$) were the less abundant rodents. A special mention must be given to *Metachirus nudicaudatus* and *Trinomys setosus*, the species with the greatest recapture indexes; the 14 individuals of *M. nudicaudatus* were captured 31 times (a 2.2 capture/individual ratio), with a single individual being captured 6 times, and the 10 specimens of *T. setosus* were captured 24 times (a 2.4 ratio), with one individual being captured 10 times.

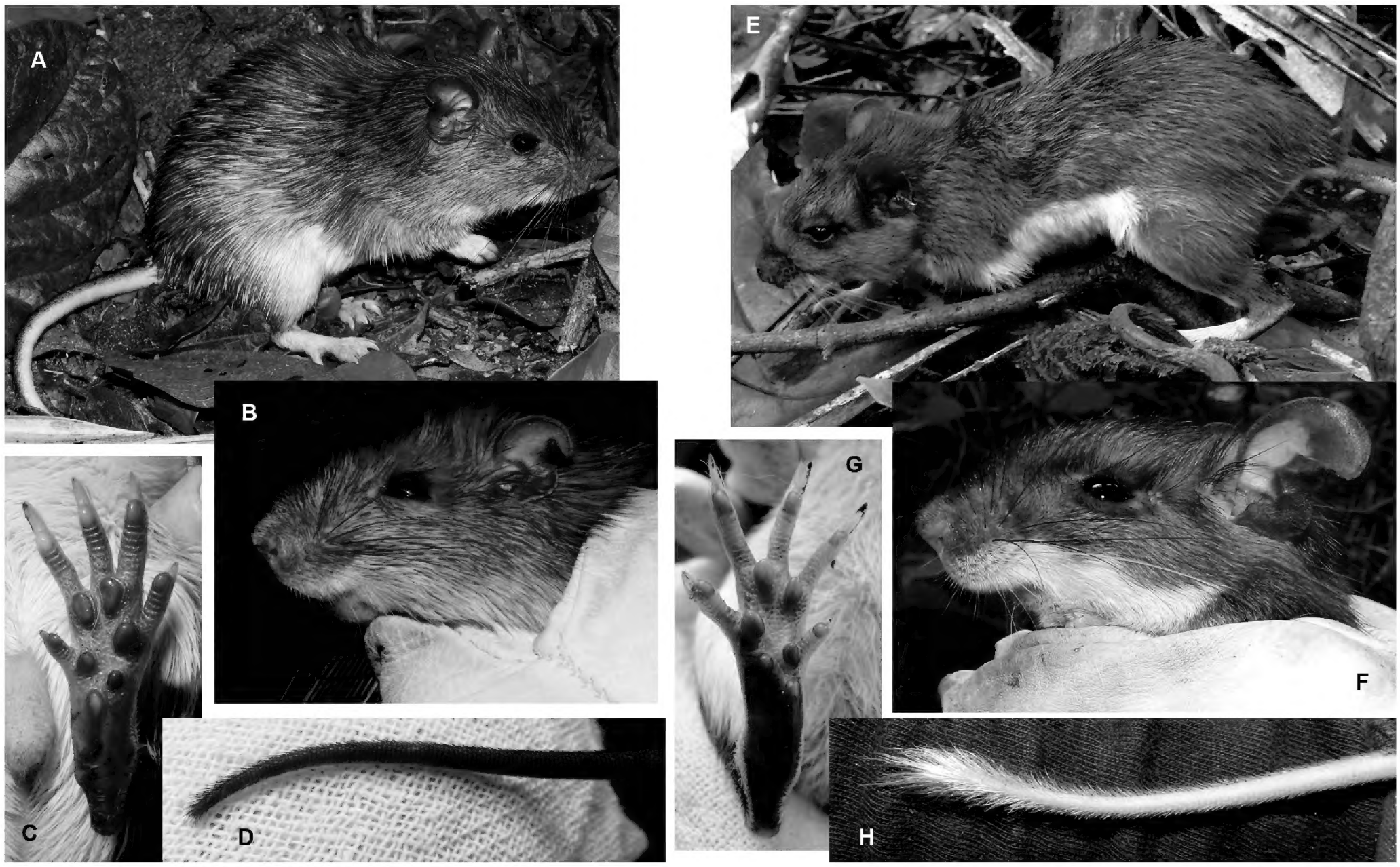

Figure 5. Echimyid rodents from the RPPN Guarirú. **A–D**, *Trinomys albispinus* (A, full body; B, detail of the head; C, detail of the left foot; D, tail without brush). **E–H**, *Trinomys setosus* (E, full body; F, detail of the head; G, detail of the right foot; H, detail of the brush tail). Note the better definition of the white areas in the belly and throat of *T. setosus*, as well the narrower appearance of its foot, when compared with *T. albispinus*. All photographs by the authors.

DISCUSSION

In spite of the relatively small area of the RPPN Guarirú, the richness of small non-volant mammals recorded in it was considerable. The most recent lists of Brazilian mammals (e.g., Paglia et al. 2012) indicate 22 didelphids, 51 cricetids, and 29 echimyids in the Atlantic Forest and, in this study, 31.8%, 5.9%, and 6.9% of these families were recorded, respectively. As already mentioned, an increase in the sampling with pitfall traps could record more species, especially rodents, as pointed out by Umetsu et al. (2006). The composition of the mammal fauna can have been biased also by the live-trap selection, once the Sherman live-traps were smaller than the Tomahawk live-traps and were often placed on the sub-canopy, while the latter were placed on the ground. The use of the mixed bait in the Sherman live-traps and banana/bacon in the Tomahawk live-traps may have influenced the captures too. In spite of it, these two traits were not evaluated in this paper.

The analysis of taxa presence in the sampling days given by EstimateS resulted in an expected richness of 12.97 ± 0.97 species, a result compatible with the 12 species recorded in this research. The rarefaction curve shows that after 37 days of effective trapping there is the beginning of stabilization (Figure 7) indicating that the sampling effort was close to ideal, although an increase in the trapping could lead to the capture of more species (what is corroborated by the fact that a different rodent species, most likely a species of *Cerradomys*, was captured during the sampling period but unfortunately the individual escaped before it was identified definitively or even photographed). Also an increase in the number of pitfall traps could record more species, once there are several rodents more capturable in this kind of trap.

The 12 species of small mammals found in RPPN Guarirú, with an area of 41 ha, does not differ much from the 13 species found by Moura (1999) in another Atlantic Forest remnant in the south of the state of Bahia. However, the area studied by this author had more than 7,000 ha and the sampling effort was greater than 7,500 traps × night (versus 1,480 here). Pardini (2004) increased the efforts of Moura (1999), sampling the same area using more than 45,500 traps × night and reached a richness of 20 species, with a greater number of rodent species (12) compared to the current work.

In another study also conducted in the south of the state of Bahia, but in a different area, Neves (2010) found a richness of 14 species, including several rodent species not recorded herein. The sampled area was also considerably greater than the RPPN Guarirú, with 9,000 ha, as well as the sampling effort of 9,600 traps × night. Velez-García (2012) developed an inventory in the RPPN Serra Bonita, also in southern Bahia, sampling 1,800 ha with 4,160 traps × night, where he found 21 small

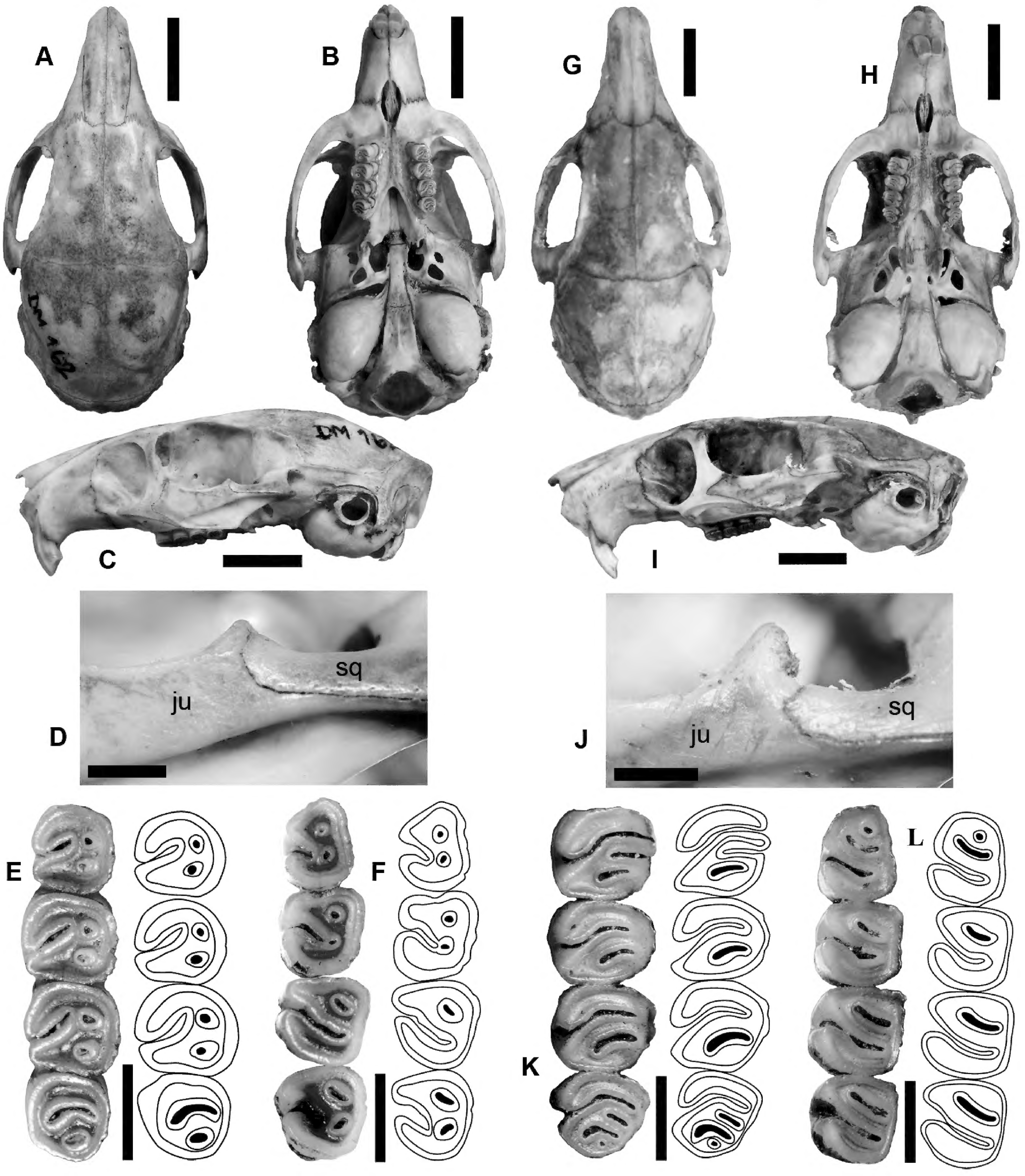

Figure 6. Skeletal and dental features of the echimyids from the RPPN Guarirú. **A–F**, *Trinomys albispinus*, MZFS DM0162 (A, skull in dorsal view; B, skull in palatal view; C, skull in left lateral view; D, detail of left jugal-squamosal suture; E, left upper premolar and molars; F, left lower premolar and molars, with the second molar being inverted from the right side). **G–L**, *T. setosus*, MZFS DM0365 (G, skull in dorsal view; H, skull in palatal view; I, skull in left lateral view; J, detail of left jugal-squamosal suture; K, left upper premolar and molars; L, right lower premolar and molars, inverted). Scale bar = 1 cm (for A-C and G-I) and 0.2 cm (for D-F and J-L). Abbreviations: ju, jugal; sq, squamosal. Note the contribution of the squamosal in the postorbital zygomatic process in *T. albispinus* versus the exclusion of the squamosal from this process in *T. setosus*; there are also great differences between the premolar and upper third molar of the two taxa.

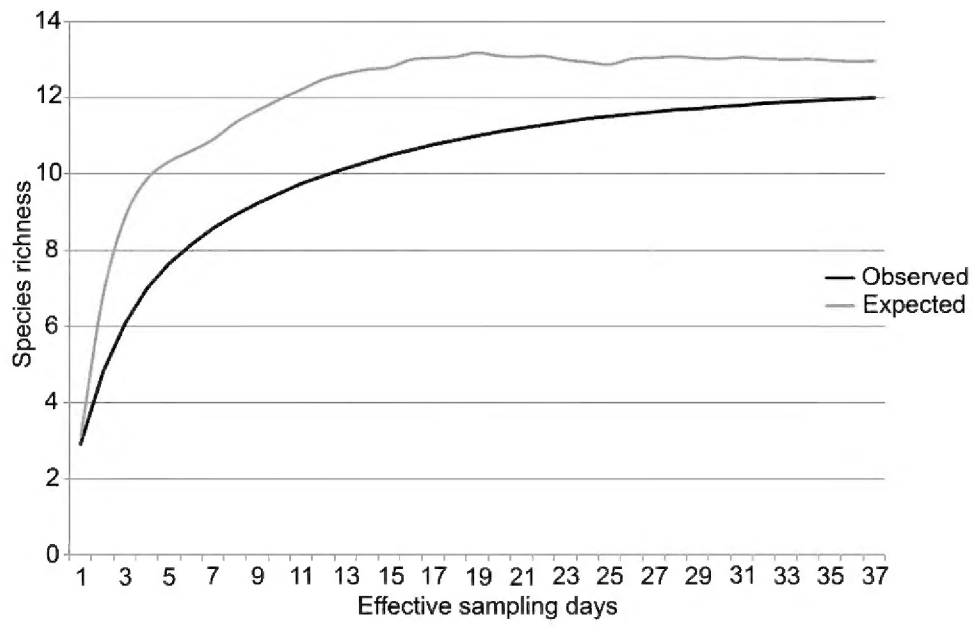

Figure 7. Rarefaction curves from the sampling effort in the RPPN Guarirú, comparing the observed and expected species richness.

non-volant mammals, with a great diversity of rodents.

Regarding the great abundance of the didelphid *Marmosops incanus* in this study, similar results were found by Moura (1999) and Neves (2010), in the state of Bahia, and Passamani and Ribeiro (2009) in the state of Espírito Santo. In these inventories, however, *Metachirus nudicaudatus*, the second more abundant species here, was one of the rarest species. The study with more similar results to the current contribution is that of Astúa et al. (2006), in the state of Espírito Santo, where *Marmosops incanus* and *Metachirus nudicaudatus* were the dominant species.

In this study the less abundant species was the undetermined *Rhipidomys*, with just one captured individual. It is the opposite situation of several studies where species of this genus, particularly *R. mastacalis* (Lund, 1840), were the most abundant species (Moura 1999; Pardini 2004; Velez-García 2012).

The historic records of *Trinomys* species in the state of Bahia are almost restricted to the collection of Moojen (1948, 1952). None of the more recent inventories conducted in Atlantic Forest remnants in this part of Brazil have recorded species of *Trinomys*, although the presence of *T. setosus* has been confirmed in a still running inventory in the southern region of this state (T.V. Oliveira, pers. comm.). The main difference is the great abundance of *Trinomys* in the RPPN Guarirú while in the south of Bahia only one individual was captured until now.

Maybe the more valuable results related to the present research are the record of *Gracilinanus microtarsus* and *Trinomys albispinus* in the Serra da Jiboia. *Gracilinanus microtarsus* is one of the smallest Neotropical marsupials occurring from the eastern forests of Brazil (from the states of Paraná to Bahia) to the Missiones province in Argentina (Emmons and Feer 1997; Eisenberg and Redford 1999; Geise and Astúa 2009). According to Geise and Astúa (2009), in the state of Bahia, *G. microtarsus* occurs in sympatry with *G. agilis* (Burmeister, 1854) in the Chapada Diamantina, with records of the former in the municipalities of Lençóis and Mucugê. Thus, its presence in the RPPN Guarirú could represent the extension of the occurrence area of the species towards the eastern part of the state of Bahia.

Regarding the echimyid *Trinomys albispinus*, it occurs in the Brazilian states of Sergipe, Bahia, and Minas Gerais, from the eastern margin of the São Francisco River (Iack-Ximenes 2005; Bonvicino et al. 2008). This species is found in areas where semi-deciduous, deciduous, and gallery forests are dominant (Iack-Ximenes 2005). Although its occurrence in the RPPN Guarirú is not important from a biogeographical approach, it is, at least, a novelty for the ecology of the species, once the area is marked by the massive dominance of Dense Ombrophilous Forest (see Figure 1).

Concerning to the reproduction of some species in the RPPN Guarirú, the most informative taxon was *Metachirus nudicaudatus* (Figure 8), with several individuals captured in different reproductive stages. Apparently, the females were reproductively active through the whole year, once pregnant (with a swollen abdomen) and lactant females were captured from August 2012 to June 2013, a result similar to that presented in Smith (2008) and Reis et al. (2011) for other regions of Brazil and South America. An interesting point is concerning the capture of a female in February, May and June 2013; in February the female was carrying eight very young cubs and in June also eight more developed cubs (with more evident ears and eyes), but in May the female was captured without any cub. As the reproductive biology of *M. nudicaudatus* is considerably unknown remains unclear if the four months between February and June were enough to the full growth of a litter and the birth of another or if the *M. nudicaudatus* females eventually gives its offspring in the nests they build (see Loretto et al. 2005) while foraging, an unusual trait among didelphids.

The RPPN Guarirú comprises only 0.2% of the extension of Serra da Jiboia. Nevertheless, given the relatively high species richness found in this study, and also the lack of mammal inventories in this important forest remnant in the state of Bahia, we conclude that this area is a significant starting point for more research and for the implantation of conservation acts and projects,

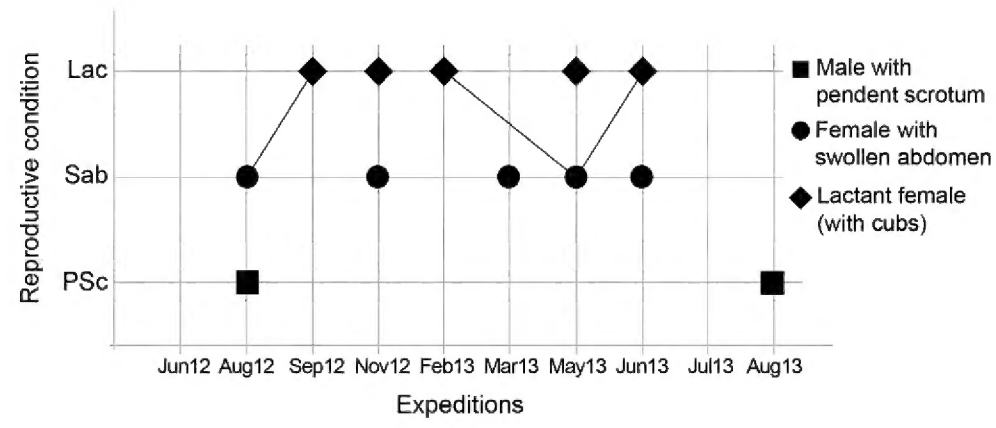

Figure 8. Reproductively active individuals of *Metachirus nudicaudatus* captured in RPPN Guarirú. The marks united by black lines represent the same individual captured in different expeditions.

since the RPPN Guarirú is the only conservation unit in this extensive mountain chain.

ACKNOWLEDGEMENTS

We thank the Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior for the Study Grant (MSC); Mr. Flávio Pantarotto for permission to access his property; Dr. Gilson Iack-Ximenes for identification of the skull and dentition of the *Trinomys* specimens; Dr. Martín Roberto del Valle Alvarez and Dr. Pedro Cordeiro-Estrela for their valuable comments during the execution of this research. We thank also an anonymous reviewer and Dr. Terrence Demos for valuable improvements on the manuscript.

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Author contributions: MSC and TVO collected the data, identified the most of the specimens, and wrote the text, and MSC carried out the analysis.

Received: 30 May 2015
Accepted: 20 September 2015
Academic editor: Terrence Demos